Chapter 6
Landslide Loss–Reduction Techniques

A significant reduction in landslide losses can be achieved by preventing or minimizing the exposure of populations and facilities to landsliding; by preventing, reducing, or managing the actual occurrence of landslides; and by physically controlling landslide-prone slopes and protecting existing structures.

Subsidized insurance is not considered a loss-reduction technique because it does not

short supply, there is strong motivation and pressure to use the land intensively. Land-use regulations must be balanced against economic considerations, political realities, and historical rights.

Various types of land-use regulations and development policies can be used to reduce landslide hazards. Some of these methods are listed in Table 2, Chapter 2. Responsibility new construction and pre-existing buildings. In rare cases, such as those involving large offshore structures, the effect of landslides can be considered explicitly as part of the design, and the facility can be built to resist landslide damage. In some cases, existing structures in landslide-prone areas can be modified to be more accommodating to landslide movement. The extent to which this is successful depends on the type of landsliding to which the structure is exposed. Facilities other than buildings (e.g., gas pipelines and water mains) can also be designed to tolerate ground movement. Codes and regulations governing grading and excavation can reduce the likelihood that construction of buildings and highways will increase the degree to which a location is prone to landslides. Various codes that have been developed for federal, state, and local implementation can be used as models for landslide-damage mitigation. A fundamental concern with design and building codes is their enforcement in a uniform and equitable way. (Committee on Ground Failure Hazards, 1985, p. 15).

Emergency Management

Emergency management and emergency planning contribute to landslide loss reduction by saving lives and reducing injuries. Such planning can also protect and preserve property in those cases where property is mobile or where protective structures can be installed if sufficient warning time is available.

Emergency management and planning consist of identifying potential hazards, determining the required actions and parties responsible for implementing mitigation actions, and ensuring the readiness of necessary emergency response personnel, equipment, supplies, and facilities. An important element of emergency management is a program of public education and awareness informing citizens of their potential exposure, installation of warning systems, types of warnings to be issued, probable evacuation routes and times available, and appropriate protective actions to be taken.

A warning system may include the monitoring of geologic and meteorologic conditions (e.g., rates of landslide movement, snowmelt runoff, storm development) with potential for causing a catastrophic event or the placement of signs instructing people within a potentially hazardous area of proper procedures (Figure 24). Automatic sensors, located within landslide-prone areas, with effective linkages to a central communication warning facility and, thence, to individuals with disaster management responsibilities, are also sometimes used. Warning systems can be long-term or temporary—used only when high risk conditions exist or while physical mitigation methods are being designed and built (Figure 25).

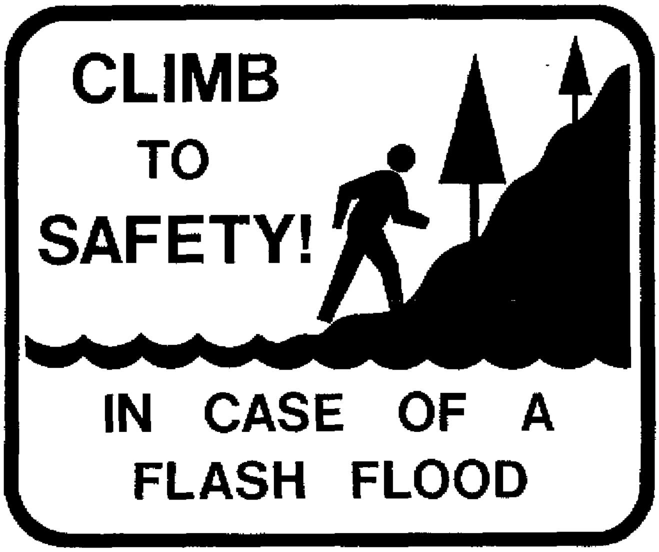
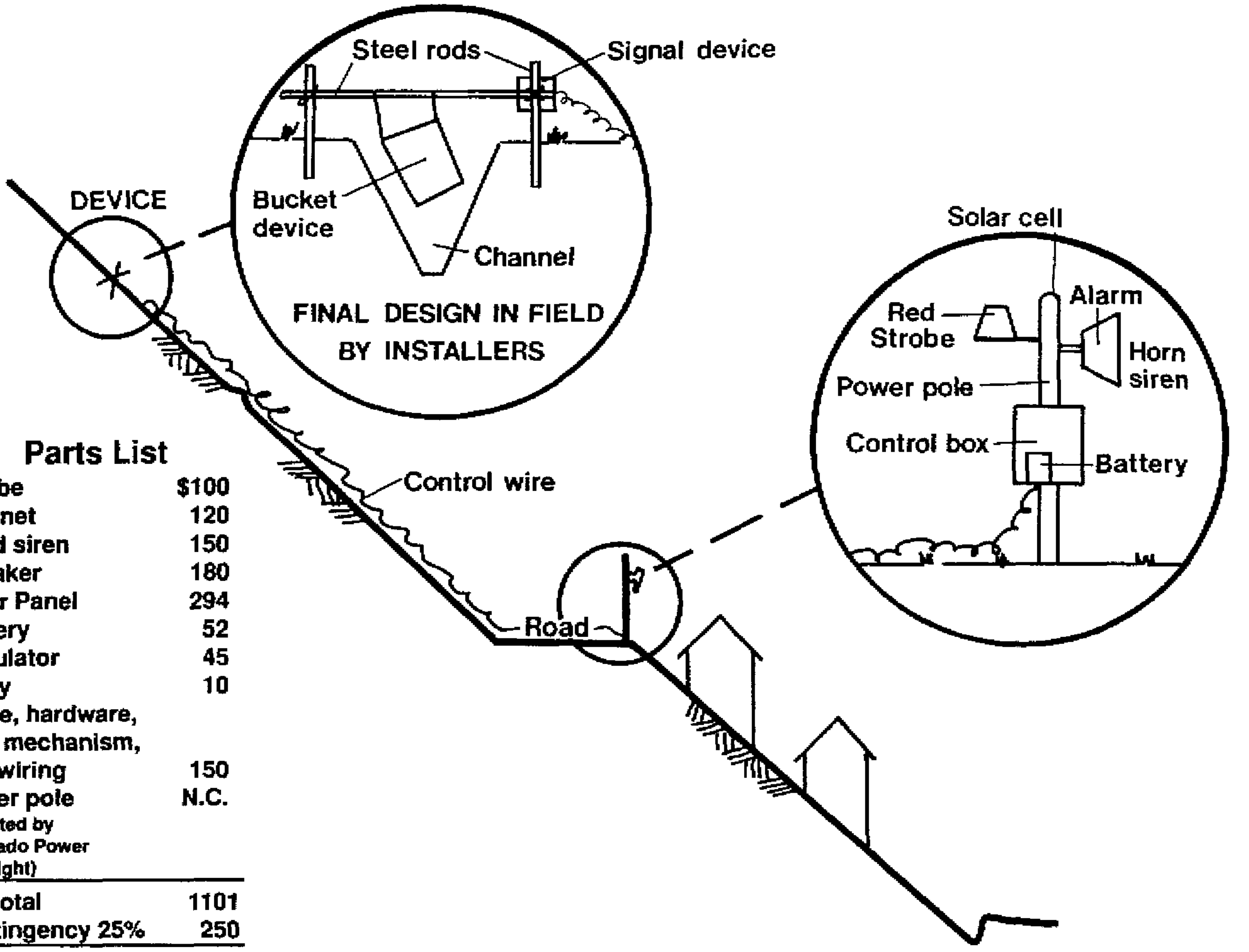


Figure 24. Sign placed in some of the hazardous mountain canyon areas of Colorado.

Controlling Landslide-Prone Slopes and Protecting Existing Structures

Physical reduction of the hazard posed by unstable slopes can be undertaken in areas where human occupation already poses a risk, but where measures such as zoning are precluded by the cost of resettlement, value or scarcity of land, or historical rights. Physical measures can attempt to either control and stabilize the hazard or to protect persons and property at risk.

It is not possible, feasible, or even necessarily desirable to prevent all slope movements. Furthermore, it may not be economically feasible to undertake physical modifications in some landslide areas. Where land is scarce, however, investment in mitigation may increase land value and make more expensive and elaborate mitigation designs feasible.



Parts List

Strobe	$100
Cabinet	120
Used siren	150
Speaker	180
Solar Panel	294
Battery	52
Regulator	45
Relay	10
Cable, hardware, gate mechanism, and wiring	150
Power pole (Donated by Colorado Power and Light)	N.C.
Subtotal	1101
Contingency 25%	250
Total	$1351

Figure 25. Schematic of a warning system (by Robert Kistner, Kistner and Associates).

Landslide control structures can be costly and usually require considerable lead time for project planning and design, land acquisition, permitting, and construction (Figure 26). Such structures may have significant environmental and socioeconomic impacts that should be considered in planning.

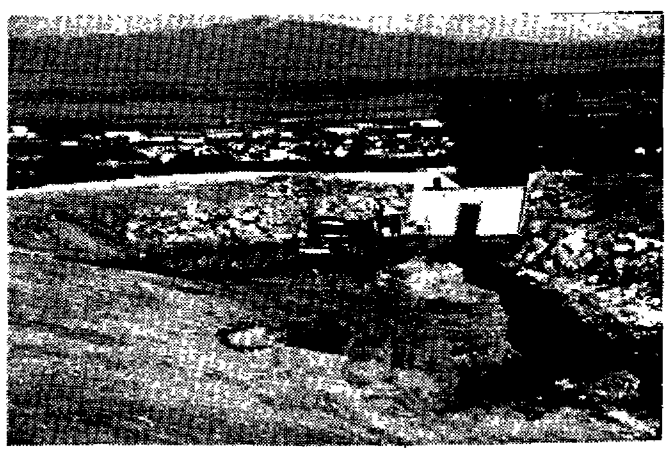


Figure 26. Rudd Creek debris basin in Farmington, Utah constructed in 1983–84 (photograph by Robert Kistner, Kistner and Associates).

Precautions Concerning Reliance on Physical Methods

Although physical techniques may be the only means for protecting existing land uses in hazard areas, sole reliance on them may create a false sense of security. An event of greater severity than that for which the project was designed may occur, or a structure may fail due to aging, changing conditions, inadequate design, or improper maintenance. The result could be catastrophic if the hazard zone has been developed intensively.

Design Considerations and Physical Mitigation Methods

When designing control measures, it is essential to look well beyond the landslide mass itself. A translational slide may propagate over great distances if the failure surface is sufficiently inclined and the shear resistance along the surface remains lower than the driving force. Debris flows can frequently be better controlled if mitigation efforts emphasize stabilizing the source area along with debris containment in the runout area. An understanding of the geological processes and the surface- and ground-water conditions, under both natural and human-imposed conditions, is essential to any mitigation planning.

Some factors that determine the choice of physical mitigation are:

- type of movement (e.g., fall, slide, avalanche, flow);
- kinds of materials involved (rock, soil, debris);
- size, location, depth of failure;
- process that initiated movement;
- people, place(s), or thing(s) affected by failure;
- potential for enlargement (certain types of failures [e.g., rotational slides, earthflows, translational slides] will enlarge during excavation);
- availability of resources (funding, labor force, materials);
- accessibility and space available for physical mitigation;
- danger to people;
- property ownership and liability.

The physical mitigation of landslides usually consists of a combination of methods. Drainage control is used most often; slope modification by cut and fill and/or buttresses is the second most frequently used method. These are also, in general, the least expensive techniques (Figure 27).

Various types of physical mitigation methods are listed in Table 6.

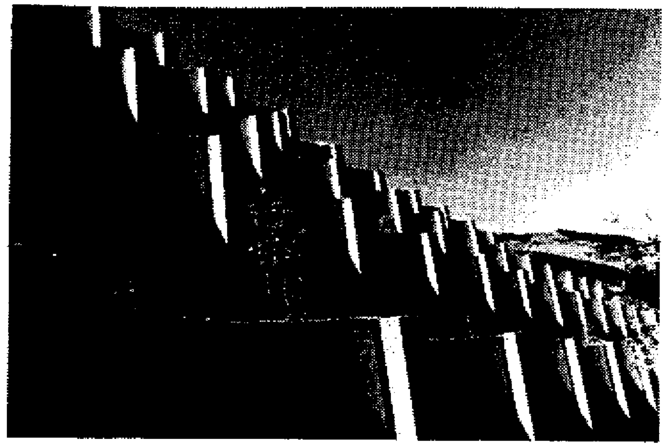


Figure 27. Retaining wall, Interstate 70, near Vail, Colorado (photograph by Colorado Geological Survey).

Table 6. Physical mitigation methods (Colorado Geological Survey et al., 1988).

A. Physical Mitigation Methods for Slides and Slumps
  1. Drainage
     a. Surface drainage
        1) ditches
        2) regrading
        3) surface sealing
     b. Subsurface drainage
        1) horizontal drains
        2) vertical drains/wells
        3) trench drains/interceptors, cut-off drains/counterforts
        4) drainage galleries or tunnels
        5) blanket drains
        6) electro-osmosis
        7) blasting
        8) subsurface barriers
  2. Excavation or regrading of the slope
     a. Total removal of landslide mass
     b. Regrading of the slope
     c. Excavation to unload the upper part of the landslide
     d. Excavation and replacement of the toe of the landslide with other materials
  3. Restraining structures
     a. Retaining walls
     b. Piles
     c. Buttresses and counterweight fills
     d. Tie rods and anchors

Table 6. Continued

- e. Rock bolts/anchors/dowels
4. Vegetation
5. Soil hardening
   - a. Chemical treatment
   - b. Freezing
   - c. Thermal treatment
   - d. Grouting

B. Physical Mitigation Methods for Debris Flows and Debris Avalanches
1. Source-area stabilization
   - a. Check dams
   - b. Revegetation
2. Energy dissipation and flow control
   - a. Check dams
   - b. Deflection walls
   - c. Debris basins
   - d. Debris fences
   - e. Deflection dams
   - f. Channelization
3. Direct protection
   - a. Impact spreading walls
   - b. Stem walls
   - c. Vegetation barriers

C. Physical Mitigation Methods for Rockfalls
1. Stabilization
   - a. Excavation
   - b. Benching
   - c. Scaling and trimming
   - d. Rock bolts/anchors/dowels
   - e. Chains and cables
   - f. Anchored mesh nets
   - g. Shotcrete
   - h. Buttresses
   - j. Dentition
2. Protection
   - a. Rock-trap ditches
   - b. Catch nets and fences
   - c. Catch walls
   - d. Rock sheds or tunnels